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QUANTITY-SPLIT STRATEGY UNDER TWO-CONTRACTOR

COMPETITIVE PROCUREMENT ENVIRONMENT

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This report discusses the various market scenarios that provide bid price manipulation opportunities under the dual source competition environment. Two different quantity-split strategies were developed one for the case when one of the suppliers does not have the capacity to produce the majority of the annual quantity requirement and the other for the case when neither contractor is interested in using low prices to capture the larger share of annual quantity.

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QUANTITY-SPLIT STRATEGY UNDER TWO-CONTRACTOR COMPETITIVE PROCUREMENT ENVIRONMENT

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EXECUTIVE SUMMARY

Given the multitude of opportunities for bid price manipulation under the dual source competition environment, this report discuss the various market scenarios that provide these opportunities. The underlying premise is that different quantity allocation methods must be developed for different scenarios.

We identify four major factors contributing to inflated bids: (1) the minimum sustaining rate, (2) the use of the minimum total cost rule, (3) unequal competitive positions, and (4) the lack of incentive to compete. The minimum sustaining rate factor is a structural issue and cannot be directly addressed. The minimum total cost rule, because of its potential effect on bid manipulation by the contractor, should be treated as an objective and not as a tool in awarding annual quantity requirements. The last two factors both contribute to a noncompetitive environment but they differ significantly from the standpoint of Government controllability. Therefore, we focus on developing quantity allocation methods for these two different environments.

When one supplier has an edge in competitive position over the other supplier, the cause of the problem must be redressed by the Government if the future competitive environment is to be improved. If the unequal position is the result of having one contractor further down the experience curve, the problem can be alleviated through the annual quantity allocation made to each contractor. The proposed quantity allocation method under this environment uses

an objective function to minimize the sum of award prices and the added costs (or savings) from competitive awards. Under unequal competitive positions, we can expect bid price inflation at low quantity from both supplier. At higher quantities, only the supplier with the competitive edge would be in a position to inflate the bid price. By minimizing the added costs, the proposed allocation procedure penalizes the supplier who inflates the bids at higher quantities and offers the other supplier an opportunity to catch up, thus improving the future competitive environment.

There are two market scenarios in which the contractors would have no incentive to engage in price competition. The first is that one of the contractors does not have the capacity to produce the majority of the annual quantity requirements. This would create a virtual monopoly for the other source at higher quantities. Since both contractors are assured of receiving the minimum sustaining rate, competitive pressure does not exist at this quantity level either. This market condition essentially is a duopoly and not a competitive one and should never be treated by the buyer as a competitive market. The same duopoly market scenario exists if neither contractor is interested in using low prices to capture the larger share of annual quantity, even if capacity is not a problem.

By using the dual source competitive bidding under this environment, the Government gives up much of the regulatory authority it enjoys over verification of the contractor's cost and

pricing data, thus allowing both contractors to exploit the market situation to their own advantage. Therefore, continuing the dual source bidding under this market scenario is to sanction the seller's profit enhancement strategies.

The difference in step-ladder bids in a particular year essentially reflects the spread of fixed costs over varying number of units produced, or the so-called production rate effect. we discuss the measurement of production rate at length and illustrate the problems of using the traditional learning curve and rate formula, which estimates the parameter value of the learning curve and the rate curve simultaneously using the same data set. Since the learning curve reflects the cumulative learning experience while the rate curve reflects the production setup, i.e., its cost structure, it is conceptually more logical and operationally more feasible to estimate the parameter of each curve with different data.

The crux of the proposed quantity allocation method under this market scenario is the bid solicitation stipulation that the step-ladder bids, after adjustment for the learning curve effect, should reflect a linear relationship on a logarithmic scale and that the line should cross the learning curve at the base production rate level, which is initially set at the same level as the directed buys. The allocation of annual quantity requirements is then made by using the minimum total cost rule.

The two quantity allocation methods discussed in this report vary in their focuses on the ground that each is intended for different market scenarios. The allocation method proposed for the market scenario with unequal competitive position has a primary objective of enhancing future competitive environments and a secondary objective of minimizing price gaming. An underlying assumption is that true savings to the Government from dual source competition is still possible if the Government can cultivate a true competitive environment. On the other hand, the allocation method proposed for the market in which competitive pressure is not present directly addresses the prevention of bid price manipulation. The underlying assumption is that true savings from dual competition is not possible because the competitive pressure is not present and the only alternative available to the Government is to ensure, within its power, that bids submitted are "honest." Our proposed allocation method is designed to provide a disincentive for bid manipulation.

While the two quantity allocation methods are intended for different market scenarios, it is also possible to have a hybrid method by combining parts of each method. For example, the bid price stipulation may be incorporated into the method proposed for the market with unequal competitive positions. However, by anchoring the rate curve at a certain point, it takes away the opportunity for truly competitive pricing along with many opportunities for price gaming.

CHAPTER 1

INTRODUCTION

A key issue facing the program manager in charge of a two-contractor weapon systems program is the allocation of annual quantity requirements among the competing suppliers. The quantity split issue is crucial for two reasons. First, it affects a contractor's bidding strategy in its pursuit of profit to compensate its investment. Second, it affects the amount the Government pays for its weapon system requirement. This report summarizes prior research related to contractor pricing strategy and Government's dual source quantity-split methods and discusses the result of our effort to develop viable methods to deal with contractors' price gaming.

CONTRACT TYPES AND WEAPON SYSTEMS PRICING

Under a sole source procurement environment, a contract is typically awarded in one of the variants of a cost-plus contract, e.g., cost-plus-fixed fee, cost-plus-negotiated fee, etc. Under FAR regulation, fixed-price negotiated contracts must follow contract cost principles and procedures.[1] Cost or pricing data are the factual portions of the proposal or the facts upon which the proposal is based and, for negotiated contracts, they are subject

[1] FAR, Part 31.

to verification by the Government.[2]

When a second source of supply is established to generate competitive pressure on the original source, a dual source competition environment is created. Implicit in the current policy and thrust on competition is the assumption that competition should result in a fair price to both the seller and the buyer and, hopefully, avoid the "exorbitant" price charged by the seller under the sole source environment. However, it is often neglected that, implicit in the doctrine of competition is the understanding that the seller and buyer will each attempt to exploit the current situation to its own advantage. The Government as the buyer hopes to procure the product or service at a lower price. The seller, on the other hand, will offer a price that will fulfill its profit objective. Which one prevails will depend on their relative position. In Chapter 2 we will illustrate that the dual source environment puts the Government in a disadvantaged position in several ways, thus allowing the contractor to utilize various price gaming strategies to obtain higher profit than would be possible under a sole source negotiation environment.

QUANTITY-SPLIT MODEL IS BOTH A MEANS AND AN END

Various quantity-split methods have been used by the Government in awarding annual quantity requirements among the two suppliers. Some have been developed with the objective of

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[2] Armed Services Pricing Manual, August 1986.

minimizing the annual cost to the Government. Others have been devised as a means to counter various price gaming strategies utilized by contractors. We recognize that annual quantity allocation among the two suppliers should be made with cost minimization in mind, but we also recognize that the way the Government splits the annual quantity affects the way the contractors determine their pricing strategy. Therefore, one must realize that the dual source quantity-split model is both an end to minimize cost and a means to influence contractors' pricing behavior.

Given the multitude of opportunities in which the contractor can manipulate bid prices under dual source competition and the different reasons behind each opportunity, it is obvious that no single quantity allocation model can become the panacea. A more logical solution is to develop different allocation methods for different market scenarios. The program manager can then assess the supply market condition and select the appropriate quantity-split method. We will proceed with this premise in mind.

BRIEF OVERVIEW OF PRIOR STUDIES

Several dual source quantity-split methods have been developed by various DoD agencies. A detailed review and evaluation of these methods can be found in our earlier report.[3] In this section, we

[3] Dan C. Boger and Shu S. Liao, "An Analysis of Quantity-Split and Nonrecurring Costs under Competitive Procurement Environment," Vol. 1, Technical Report, Naval Postgraduate School, Monterey, CA., September 1985.

will briefly review the intent of each method.

The minimum cost rule computes the total cost to the Government for each quantity combination and selects the least cost alternative.[4] The emphasis here is on ensuring that the government incurs only the minimum annual cost **after** the contractors submitted their bids.

Solinsky developed a mathematical model for the Army Electronics Command during the competitive production of the AN/PVS-5A.[5] The method was developed primarily as a means of enhancing aggressive bidding by relating the split in the annual award quantity to the difference in bid prices between the two suppliers.

An elaborate procedure was developed by Pelzer for the Air Force GAU-8 ammunition program.[6] This method specifically incorporates quality and the contractor's price decreases over the last three years into the quantity award determination. The objective of this model is on rewarding good product quality and a steep price reduction curve.

The Air Force A-10 Program used a dual competitive award method which requires each contractor to provide a price reduction

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[4] See J. A. Muller, "Competitive Missile Procurement," Army Logistician, Vol. 4., No. 6 (November-December 1972).

[5] Kenneth S. Solinsky, "A Procurement Strategy for Achieving Effective Competitive Competition While Preserving an Industrial Mobilization Base," undated report, Army Electronics R. & D. Command, Night Vision and Electro-Optics Laboratory.

[6] Jay L. Pelzer, "Proposed Allocation Technique for a Two-Contractor Procurement," Air Force Institute of Technology, May 1979.

curve that reflects the bids submitted for various quantities.[7] The bid prices are then averaged for each contractor and the difference between the two average bids is used for quantity allocation.

From this brief review of quantity allocation practices, it should be obvious to the reader that different quantity allocation models have been developed as a means to induce or coerce the contractor to conform to the Government's objective. Whether or not these attempts can bring about the desired result depends upon the market scenario, however.

OBJECTIVES AND METHODOLOGY

Given the multitude of opportunities for bid price manipulation, our objective is to develop different quantity allocation methods for different market scenarios. Our study is based on the premise that achieving minimum cost to the Government for one year does not necessarily result in the lowest cost over the long run. Therefore, a certain degree of trade-off between minimizing annual outlay and enhancing the competitive environment is necessary.

In Chapter 2 we will discuss various market scenarios that provide opportunities for bid price manipulation by the contractor. An appropriate quantity allocation method will be developed for each scenario. Numerical examples will be used to illustrate the algorithm.

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[7] Darrell R. Hoppe, "Dual Award and Competition -- You Can Have Both," paper presented at the 1977 Acquisition Research Symposium.

CHAPTER 2

ANALYSIS OF WEAPON SYSTEMS PRICING STRATEGIES

Dual source competition allows the contractor and the government opportunities to exploit the market situation to each party's own advantage. The government's objective is that competition will put competitive pressure on the supplier and result in a fair price to both parties. However, dual source competition also creates opportunities for the contractor to exploit. First, in return for the competitive market pressure with competitive bidding, the government gives up much of the regulatory authority it enjoys over verification of the contractor's cost and pricing data. Thus, it becomes easier for the contractor to obtain higher profit under a dual source competitive contract than under a sole source negotiated contract if the market environment allows it. Second, in order to maintain two sources of supply, it is necessary to award a minimum sustaining quantity to the higher-priced competitor. Both of these two factors put the Government in a disadvantaged position in dealing with the contractors. In this chapter, we will discuss various pricing strategies that can be used by the contractor to exploit the dual source competition situation. The discussions in this chapter will form the basis for developing quantity split methods suitable for the appropriate market environment.

THE STRUCTURAL OPPORTUNITIES

The Minimum Sustaining Rate

In a dual source competition environment, the lower-priced bidder is typically awarded the major portion of the annual quantity, but the higher bidder is also awarded a quantity that represents the minimum level of production the contractor requires to stay in production and remain viable. This guarantee, resulting from the desire to maintain two viable production sources, may diminish competitive pressures and put the government in a disadvantaged position. As a matter of fact, there is no competitive pressure at the minimum sustaining quantity level and the Government can expect an inflated bid price from each of the two suppliers at this level.

Production Rate Effect

Due to the splitting of the production quantity between the two contractors, the Government must forego some of the savings associated with cumulative production experience. The smaller production rate also means high unit cost because neither contractor is able to fully realize the economies of scale. Therefore, the split award should result in higher production cost to the contractor than awarding the entire year's production buy to the low bidder for the given year. The argument for using dual source competition, of course, rests on the assumption that the bid prices should be lower under a competitive environment, compared

to a sole source acquisition, thus resulting in net savings to the Government.

UNEQUAL COMPETITIVE POSITION BETWEEN CONTRACTORS

If the second supplier is established after the first supplier has had some production experience with the weapon system in question, the competitive position of the two contractors may be unequal. Under this circumstance, the anticipated competitive pressure from dual sourcing may diminish, or even evaporate completely.

The First Supplier Is Further Down the Learning Curve

Being the developer of the system and having had some production experience, the first supplier often enjoys a cost advantage over the new supplier. Other things being equal, the more experienced producer will have a lower production cost and can under-bid the new supplier. This problem is compounded if the first supplier continues to win the majority of annual quantities on a dual award environment.

The Second Supplier's Capacity Is Limited

There is a dilemma facing the Government in establishing the second supply source. The combined production capacity may far exceed the actual requirements if the second source is established at the same production capacity level as the original source. On the other hand, if the second source's production capacity is

established at a lower level than the first source, the second source would not be in a position to bid at the higher percentages of the annual requirement, thus creating a virtual monopoly for the original source at higher quantities.

OPPORTUNITIES CREATED BY OTHER PARTIES' ACTIONS

In addition to the structural opportunities and unequal competitive position, a contractor can also take advantage of other parties' actions and exploit the dual source competition environment.

Government's Attempt to Minimize the Total Cost

The logical and widely used quantity allocation method involves computing the total cost to the government for each quantity split combination and selecting the least cost alternative. This method would ensure that the government incurs only the minimum cost possible according to the bid prices submitted by the competitors. However, this quantity allocation method also encourages the contractor to "front load" the bids. By raising its bids on the smaller quantities, a contractor can increase its chance of getting the larger portion of the annual buy.

Table 2.1 illustrates this price gaming. Part A assumes that the bid prices submitted by both suppliers are realistic. Under this circumstance, the minimum cost to the Government is $590, which results from awarding 70% of the annual quantity to X and

30% to Y. Since X is the low price bidder, it is fair for X to be awarded the majority of the quantity. Now let us assume that Y is also interested in capturing the majority of the quantity but cannot compete on price because of its higher cost. If Y deliberately inflates its bid price for the low quantity, it is conceivable that Y would end up being the winner if the minimum total cost method is used for quantity allocation. Part B illustrates this scenario. Although the $630 total is the lowest of the three quantity combinations, it is not the true minimum total cost because the bid prices include padding induced by the government's quantity allocation method.

Table 2.1

Price Manipulation Under the Minimum Cost Method

Contractor X			Contractor Y			Total
Quantity	Bid	Total	Quantity	Bid	Total	Cost
A: No Price Gaming						
30	$70	$210	70	$60	$420	$630
50	60	300	50	70	350	650
70	**50**	**350**	**30**	**80**	**240**	**590** *
B: With Price Gaming						
30	**$70**	**$210**	**70**	**$60**	**$420**	**$630** *
50	60	300	50	70	350	650
70	50	350	30	95	285	535

* Minimum total cost.

Lack of Incentive to Compete under Duopoly

In economic theory, competition implies that there is a large

number of suppliers. Dual source "competition" is in essence a misnomer, as there are only two suppliers. Under duopoly, each supplier is concerned about what the other supplier does. If one supplier senses that the other supplier has no economic incentive or is not in a position to engage in price competition, the pressure of competition disappears and both suppliers can charge what the market can bear. This is probably the worst scenario faced by the Government, as it loses much of its regulatory power under the so-called "competitive" acquisition.

SUMMARY OF PRICE GAMING SCENARIOS

Since different market scenarios call for different quantity allocation methods, a summary of opportunities created by dual sourcing and their resultant pricing strategies would facilitate understanding of the quantity allocation methods to be discussed in the next chapter:

	Inflated bids at		
	low quantity	high quantity	all quantity
Minimum sustaining rate	X		
Unequal competitive positions	X	X	X
Use of minimum total cost rule	X		
Lack of incentive to compete	X	X	X

We may infer that under a dual source environment neither

contractor would have any logical reason to submit a competitive bid price for the low quantity portion of the annual requirement. If the competitive position of the two contractors are not equal or the economic condition does not offer any incentive for the contractors to compete in price, then the market is essentially noncompetitive. It should be emphasized that the scenarios contributing to this noncompetitive environment are significantly different from the standpoint of Government controllability and therefore require different counter-strategies. In the case of unequal competitive position, the cause of the problem can be redressed by the Government's remedial action to improve the future competitive environment. On the other hand, if the economic environment does not offer any incentive for the contractor to compete in price, the procuring agency can only deal with the symptom, but not the cause. Therefore, different quantity split methods must be developed for these two market scenarios.

The effect of a production rate decrease on a contractor's production cost is a structural issue and the resulting cost increase can be justified. Therefore, no additional action by the Government is necessary except to ensure that the cost increase is reasonable.

Of course, the minimum total cost rule should remain a major factor in every quantity allocation method. However, because of its potential effect on bid price manipulation by the contractor, the minimum total cost rule should be treated as a major objective but not as the only tool in awarding annual quantity requirements.

CHAPTER 3

A QUANTITY SPLIT METHOD FOR UNEQUAL COMPETITIVE POSITIONS

When one supplier has an edge in competitive position over the other supplier, the cause of the problem must be redressed by the Government if the future competitive environment is to be improved. If the unequal position is the result of having one contractor further down the experience curve, the problem can be alleviated through the annual quantity allocation made to each contractor. In this chapter, we will present the quantity allocation procedure under this environment. The objective function of the proposed allocation procedure is to minimize the sum of award prices and the added costs (or savings) from competitive awards. Under unequal competitive positions, we can expect bid price inflation at low quantity from both supplier. At higher quantity, only the supplier with the competitive edge would be in a position to inflate the bid price. By minimizing the added costs, the proposed allocation procedure penalizes the supplier who inflates the bids at higher quantity and offers the other supplier an opportunity to catch up, thus improving the future competitive environment. For convenience of presentation, some variables are abbreviated. Appendix A lists definitions of abbreviations and variables used in this chapter.

ASSUMPTIONS AND REQUIREMENTS

Several assumptions and conditions are required in our discussion of the quantity allocation method. The following

modifications and assumptions are applicable unless specified otherwise:

1. Each contractor has received at least two separate annual awards for a quantity of units in which the prices were negotiated. The negotiated prices are crucial to the development of the proposed award allocation technique and its subsequent effectiveness. The objectives of the government procurement team address this by ensuring, to the maximum extent practicable, that the final negotiated award prices are reasonable and fair to both transaction parties. The initial two or more annual program awards for each individual contractor, which involved negotiated pricing, sufficiently reflect their particular existing learning curve effect.

2. The initial awards for each contractor, which were negotiated-price directed buys, were each for an equal quantity of units. This permits development of each contractor's learning curve with equivalent annual production rates. On the other hand, if equal quantity awards for each year are impractical, a hypothetical price for the same quantity as the first year should be negotiated even though the award quantity will be different.

3. Each contractor will be able to deliver all quantities it has bid on in a timely manner and in the condition as specified in the contract. This will hold the bidding contractors to the terms of the solicitation and contracts issued.

4. The units produced by the contractor are assumed to be identical in performance characteristics and technical specifications.

5. Annual procurement solicitations requested bids in a specified step-ladder format.

6. The contracts involved, whether negotiated or dual source competed, are firm-fixed-price contracts.

7. All prices, whether negotiated or bid, are based on constant dollars, using DoD escalation indices for price level adjustments.

8. No significant competitive advantage (Government Facilities, Transportation Factors, Government Furnished Materials, etc.) is involved.

OVERVIEW OF THE ALLOCATION TECHNIQUE

The following six steps briefly describe the proposed quantity-split technique for the dual source competitive situation. A more detailed discussion of these individual steps, along with illustrative examples, will follow.

Step 1: Calculate the Necessary Learning Curves.

A learning curve is established for each contractor by using their respective, initial two or more annual program awards. These were directed buys and their prices were determined by negotiation. Beltramo's method used the negotiated prices that already existed for current and past programs.[1] The directed buy initial awards, associated with this allocation technique, were recommended to have their prices negotiated with this particular learning curve determination in mind.

Step 2: Request Step-ladder Bids.

Request step-ladder bids from each contractor for a range of specific quantities or percentages of the total annual buy requirement when each annual procurement solicitation occurs. The lowest quantity that bids should be requested for is the MSR.

Step 3: Construct the Technique's Objective Function.

This quantity-split technique's mathematical objective function is used to determine the annual award allocation quantities. This objective function, which is to be minimized, is composed of two specific factors from each contractor's procurement data. The objective function is defined by adding all these two factors together.

The first factor is the total bid cost charged to the government for the particular award quantity under consideration. This factor is included so that the objective function attempts to attain the minimum total bid cost charged to the government in order to satisfy the annual procurement requirement.

The second factor is an estimated measure of the added

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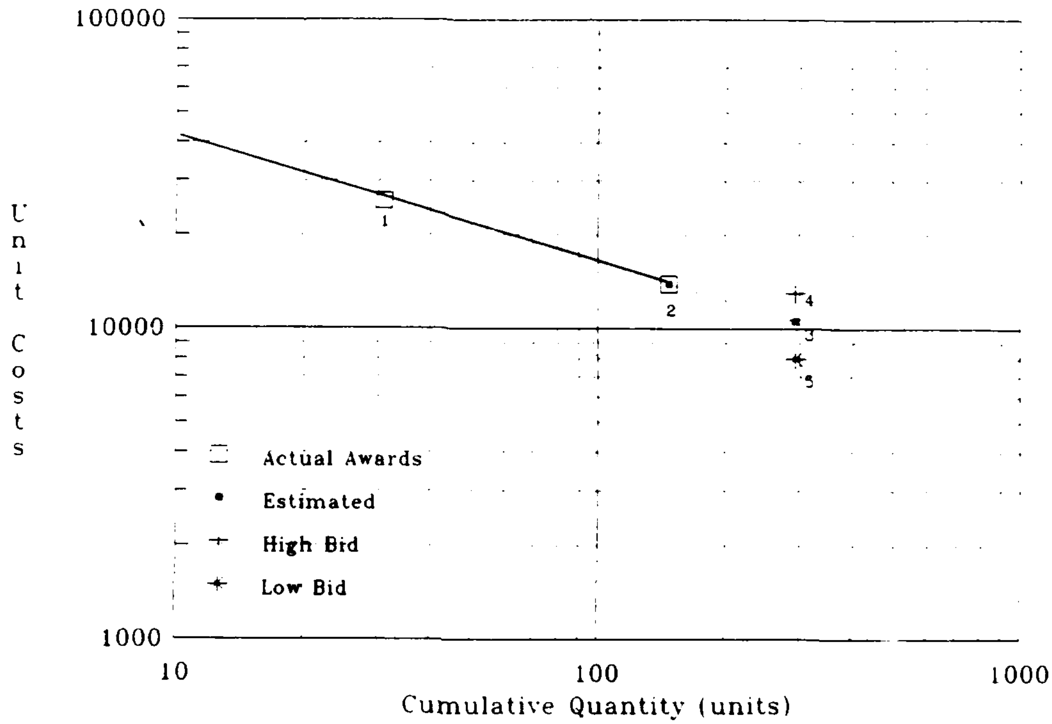
[1] M. C. Beltramo, "A Case Study of the Sparrow AIM-7F," Program Manager, Vol. XIV, No. 5 (September-October), pp. 28-35.

costs or savings resulting from competition. By incorporating this factor into the objective function, the process of selecting the suggested award allocation attempts to minimize the added costs, or maximize the savings, resulting from competition.[2]

Figure 3.1
Estimated Savings/Additional Costs



The methodology used to estimated savings or added costs resulting from competition involves extrapolating the learning curve established by prior award quantity data and their corresponding negotiated prices. Assume Points # 1 and 2 in Figure 3.1 represent prior award quantity data and the solid line passing through them the resultant learning curve, the learning curve may be extrapolated as shown by the dashed line. Point #3 in Figure 3.1 may be

[2] L. A. Kratz, J. W. Drinnon, and J. B. Hiller, Establishing Competitive Production Sources, Defense Systems Management College, 1984; Beltramo, op. cit., pp. 28-35.

interpreted as the estimated cost for the next contract award of the same lot quantity as in previous awards. If the estimated cost is larger than the bid cost, then the difference represents an estimated savings due to competition and results in a negative value for that particular contractor's second factor in the objective function. This situation is shown by Point #5 Figure 3.1. If the estimated cost for the particular award quantity being considered was less than the bid price, then the difference represents an estimated added cost due to the competition and is reflected in a positive value in the objective function for that particular contractor's second factor. This is the case for Point #4 in Figure 3.1. Since the estimated added costs due to competition represent the effect of contractor price gaming and production rate change [Ref. 7: p. 59], the objective function attempts to reduce this effect.

Step 4: Substitute step-ladder bid data into the Objective Function.

Substitute the pertinent data from each contractor and calculate total bid cost and estimated cost differential for each quantity-split combination.

Step 5: Determine the Recommended Award Allocation.

Determine the quantity-split combination which results in the minimum value in the objective function.

Step 6: Determine Total Annual Award Cost.

From the annual award allocation computed in Step 5, determine the total cost to the government for the annual procurement requirement.

ILLUSTRATION OF THE ALLOCATION TECHNIQUE

This technique's six steps briefly mentioned above will be illustrated in this section. All monetary values involved must be expressed in constant dollars. We will use a missile program identified as X for illustration purpose.

Step 1: Calculate the Necessary Learning Curves.

a. List Initial Awards Data

Arrange the quantity and negotiated price data, from the initial two or more awards for each contractor. Table 3.1 illustrates this procedure for Program X.

Table 3.1

INITIAL NEGOTIATED ANNUAL AWARDS FOR PROGRAM X
(FY1986 $)

	Contractor A			Contractor B		
Year	Quantity Q-A	Unit Cost CAN-A	Total Cost CTN-A	Quantity Q-B	Unit Cost CAN-B	Total Cost CTN-B
1985	500	2,800	1,400,000	---	---	
1986	500	2,500	1,250,000	500	3,450	1,725,000
1987	500	1,700	850,000	500	2,750	1,375,000

Q-A = Quantity of Contractor A's Annual Award
Q-B = Quantity of Contractor B's Annual Award
CAN-A = Cost, Average Unit Negotiated, for Contractor A's Award
CAN-B = Cost, Average Unit Negotiated, for Contractor B's Award
CTN-A = Cost, Total Negotiated for Contractor A's Annual Award
CTN-B = Cost, Total Negotiated for Contractor B's Annual Award

b. Determine Algebraic Midpoints

Estimate the algebraic midpoint (M) of each lot which is necessary for developing the average incremental unit cost learning curve. These algebraic midpoints are where the annual award's estimated average unit cost on the curve equals the average unit cost for the entire annual award. In order to estimate these midpoints, the following commonly used formulas are applied:

$$\text{First Award Midpoint} = \frac{L + 1}{3} + 0.5$$

$$\text{Subsequent Award Midpoint} = \frac{L}{2} + \text{Sum of all preceding lots}$$

The algebraic lot midpoints for Program X data shown in Table 3.1 are:

Lot	Contractor A	Contractor B
1985	167.5	---
1986	750.0	167.5
1987	1,250.0	750.0

d. Determine the Learning Curves

If there are three or more data points available, the standard least squares regression method may be used to determine the learning curve for each contractor. This learning curve is in the power curve equation form

$$CAN = aM^b$$

where CAN = Average negotiated cost per unit
a = the theoretical first unit cost
M = lot midpoint
b = the learning curve slope

If there are only two data points available for analysis, the following formula may be used, as most computer software would not calculate the equation:

$$b = \frac{\text{Log}(CAN_2/CAN_1)}{\text{Log}(M_2/M_1)}$$

The learning curve equations computed from Table 3.1 data are shown below:

Contractor	Equation	Slope
A	$CAN\text{-}A = 8{,}512.260M^{(-.2092)}$	86.50177%
B	$CAN\text{-}B = 7{,}486.084M^{(-.1513)}$	90.04549%

Step 2: Request Step-ladder Bids

Figure 3.2
Program X - Contractor A Price Data

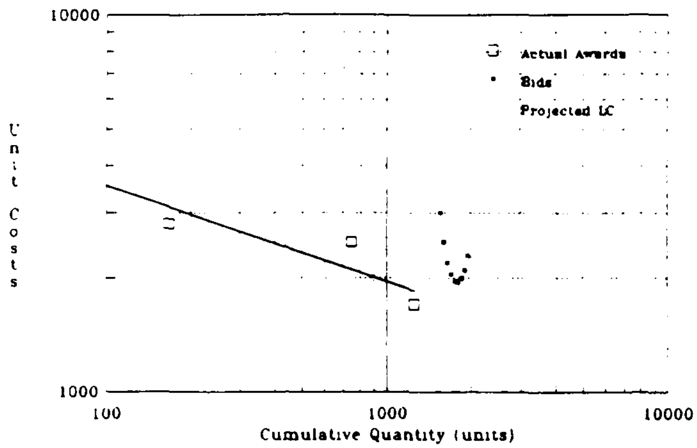
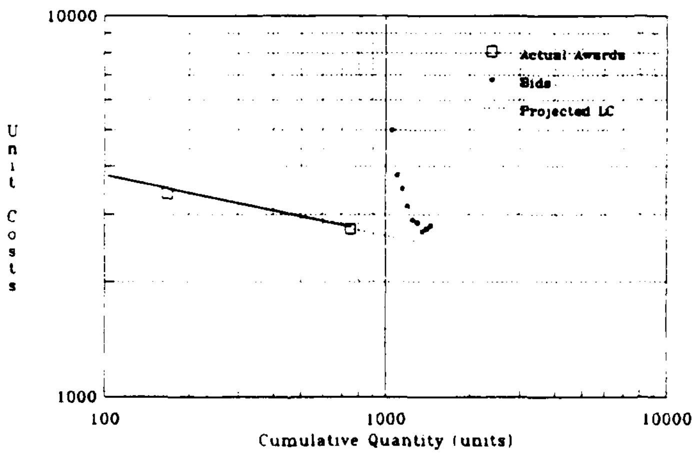


Figure 3.3
Program X - Contractor B Price Data



Solicit bids in a step-ladder format to achieve full and open competition as required by The Competition In Contracting Act (CICA).[3] Table 3.2 shows the hypothetical step-ladder bids for

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[3] PL 98-369.

FY1988 requirements from the two contractors of Program X. These step-ladder bids are illustrated with log-log graphs in Figures 3.2 and 3.3 for contractors A and B respectively. The bid data plotted are, M-A with CAB-A in Figure 3.2 and M-B with CAB-B in Figure 3.3. These plotted data are referred to as step-ladder "bids" for FY1988 buy in the legend of both figures.

Table 3.2

FY1988 ANNUAL AWARD STEP-LADDER BIDS FOR PROGRAM X
(Total annual award quantity, QT = 1000 units)
(FY1986 $)

Contractor A

% QT	Quantity Q-A	Midpoint M-A	Average Bid Price CAB-A	Total Cost CTB-A
10	100	1,550	3,000	300,000
20	200	1,600	2,500	500,000
30	300	1,650	2,200	660,000
40	400	1,700	2,050	820,000
50	500	1,750	1,960	980,000
60	600	1,800	1,950	1,170,000
70	700	1,850	2,000	1,400,000
80	800	1,900	2,100	1,680,000
90	900	1,950	2,300	2,070,000

Contractor B

% QT	Quantity Q-B	Midpoint M-B	Average Bid Price CAB-B	Total Cost CTB-B
10	100	1,050	5,000	500,000
20	200	1,100	3,800	760,000
30	300	1,150	3,500	1,050,000
40	400	1,200	3,100	1,240,000
50	500	1,250	2,900	1,430,000
60	600	1,300	2,850	1,710,000
70	700	1,350	2,700	1,890,000
80	800	1,400	2,750	2,200,000
90	900	1,450	2,800	2,520,000

CAB-A = Average Unit Cost bid by Contractor A
CAB-B = Average Unit Cost bid by Contractor B
CTB-A = Total Bid Cost for that quantity from Contractor A
CTB-B = Total Bid Cost for that quantity from Contractor B

The bid data are constructed to reflect the typical price gaming behaviors discussed in Chapter 2. Front loading is the inflation of quotes for the smaller award quantities. This strategy is observed in the plotted step-ladder bids for FY1988 by the steep upward bend at the low end of quantities. In our example, Contractor B has cumulatively produced less missiles than Contractor A prior to the FY1988 procurement solicitation. Thus, Contractor B could believe that Contractor A has a sufficient cost advantage to win a majority of the annual award. Therefore, Contractor B could possibly attempt to generate higher profits at a lower annual award quantity. This situation could be reflected by Contractor B having a more pronounced (steeper) front loaded price gaming strategy than Contractor A, as illustrated in Figures 3.2 and 3.3.

End loading, bid price inflation of the larger annual award amounts, is reflected by the upward curvature of bids at the high end of the award quantities. In the Program X example, Contractor A features a higher degree of end loading than Contractor B which could suggest it believes Contractor B does not have enough production experience to be the lower bidder.

The strategy of price inflation over the entire quantity range is self-explanatory. This strategy is depicted in Figures 3.2 and 3.3 for Contractors A and B respectively by the FY1988 step-ladder bids being consistently above their associated extrapolated actual award learning curves. Also, in each contrac-

tor's case, the FY1988 quote for 500 units was higher than the negotiated award of 500 units for the prior fiscal year.

Step 3: Construct the Objective Function

The proposed quantity allocation technique uses an objective function, similar to the linear programming context, to determine the annual award allocation. The decision variables are the specific quantities to allocate to each producer as an annual award. The decision variables for Program X are therefore Q-A and Q-B. The objective function value in this method is a "total pseudo-cost" henceforth referred to as "Z". This technique selects the annual award allocation combination which results in the minimum value (in constant dollar units) for Z. Only those combinations of contractor award quantities which exactly satisfy the total annual procurement requirement (QT) can be considered.

The objective function addresses two primary concerns in determining its recommended annual award allocation. In order to stress the concern for minimizing the cost to the government, the objective function incorporates the total bid cost for the procurement requirement, for each award combination considered. A measure of the competitiveness of the bids, the difference between the bid and estimated costs, is incorporated into the objective function in order to address concerns for minimizing contractor price gaming and production rate inefficiencies.

The objective function requires two specific items of information, from the data on each contractor, in order to

determine the value of Z. The necessary pieces of information are the total bid price, and the estimated total negotiated price, associated with each acceptable award combination.

The objective function incorporates factors which enable it to simultaneously consider both the total requirement recurring cost and the estimated total requirement recurring cost differential. This differential will henceforth be called the "estimated total cost differential." It is the difference between the total recurring costs for an annual requirement when determined from bid prices and when determined from estimated negotiated prices.[4]

The factors that incorporate concerns for the minimum total cost into the objective function are the total bid costs from the specific award combinations. For Program X these factors are the total bid costs for A (CTB-A) and B (CTB-B) respectively.

The estimated total cost differentials are obtained by subtracting the estimated total negotiated costs from their associated total bid costs. These differentials correspond to the estimated additional recurring costs (for positive values) or the estimated recurring cost savings (for negative values) resulting from the use of competition instead of negotiation for award price

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[4] Michael N. Beltramo, "A Case Study of the Sparrow AIM-7F,' Program Manager, Vol. XIV, No. 5 (October 1985), pp.29-31.

determination.[5] The estimated total negotiated costs are determined by inserting the algebraic midpoint (M) of the quantity involved into the corresponding contractor's extrapolated learning curve equation. The resulting value (CAB) is then multiplied by the quantity involved to yield estimated total negotiated costs. The estimated total cost differential is substituted into the objective function to compute the value of Z.

For Program X, the estimated negotiated costs (Est. CTN-A and Est. CTN-B) are determined by extrapolating the learning curves and multiplying the estimated unit price (CAN) by the quantity, as shown below:

$$\text{Est. CTN-A} = \text{Est. CAN-A} * \text{Q-A}$$
$$= 8{,}512.260 * \text{M-A}^{(-.2092)} * \text{Q-A}$$

$$\text{Est. CTN-B} = \text{Est. CAN-B} * \text{Q-B}$$
$$= 7{,}486.084 * \text{M-B}^{(-.1513)} * \text{Q-B}$$

$$\text{Est. CTD-A} = \text{CTB-A} - \text{Est. CTN-A}$$

$$\text{Est. CTD-B} = \text{CTB-B} - \text{Est. CTN-B}$$

where:

Est. CTN-A = Estimated Total Negotiated Cost of an annual award quantity to Contractor A as determined with extrapolation of the corresponding established learning curve involved.

Est. CTN-B = Estimated Total Negotiated Cost of an annual award quantity to Contractor B as determined with extrapolation of the corresponding established learning curve involved.

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[5] E. T. Lovett and M. G. Norton, "Determining and Forecasting Savings from Competing Previously Sole Source/Noncompetitive Contracts," Army Procurement Research Office, APRO 709-3, October 1978; Kratz, Drinnon, and Hiller, op. cit.

Est. CTD-A = Estimated Total Cost Differential included in the associated Total Bid Cost for an annual procurement quantity for Contractor A. It is the difference between the Total Bid Cost and Estimated Total Negotiated Cost at that quantity.

Est. CTD-B = Estimated Total Cost differential included in the associated Total Bid Cost for an annual procurement quantity for Contractor B. It is the difference between the Total Bid Cost and Estimated Total Negotiated Cost at that quantity.

In order to consider the total cost and estimated total cost differential simultaneously, these two cost items are added together for each individual contractor. So, the factors from each contractor used in the objective function would be:

Objective Function Factors from each contractor =
Total Bid Cost to obtain a particular quantity from the contractor (CTB) + The associated Estimated Total Cost Differential for that contractor (CTD)

The objective function is then defined by adding together the factors from each contractor into one equation as follows:

Objective Function:

Minimize: Z = Total Bid Cost to obtain a particular quantity from A + The associated Estimated Total Cost Differential for A + Total Bid Cost to obtain a particular quantity from B + The associated Estimated Total Cost Differential for B

or Minimize Z = (CTB-A + CTD-A) + (CTB-B + CTD-B)

Step 4: Substitute Data from Quantity-splits into Z

a. Evaluate Input Variables for Objective Function

For each quantity-split combination (C), determine its specific variables which are used in the objective function. For Program X the input variables are computed as shown in Table 3.3.

Table 3.3

OBJECTIVE FUNCTION VALUES FOR EACH QUANTITY-SPLIT LEVEL
(QT = 1,000 units)

Contractor A

C	%QT	Q-A	CTB-A	Est. CTN-A	Est. CTD-A
1	10	100	300,000	183,076.37	116,923.63
2	20	200	500,000	363,728.89	136,271.11
3	30	300	660,000	542,092.42	117,907.58
4	40	400	820,000	718,290.00	101,710.00
5	50	500	980,000	892,434.20	87,565.80
6	60	600	1,170,000	1,064,628.30	105,371.66
7	70	700	1,400,000	1,234,967.40	165,032.55
8	80	800	1,680,000	1,403,539.20	276,460.80
9	90	900	2,070,000	1,570,424.60	499,575.36

Contractor B

C	%QT	Q-B	CTB-B	Est. CTN-B	Est. CTD-B
1	90	900	2,520,000	261,352.89	279,915.39
2	80	800	2,200,000	519,040.27	198,215.55
3	70	700	1,890,000	773,342.62	128,775.88
4	60	600	1,710,000	1,024,506.30	191,736.05
5	50	500	1,450,000	1,272,748.90	177,251.09
6	40	400	1,240,000	1,518,263.90	215,493.72
7	30	300	1,050,000	1,761,224.10	276,657.38
8	20	200	760,000	2,001,784.40	240,959.73
9	10	100	500,000	2,240,084.60	238,647.11

b. Calculate the Objective Function (Z)

With the values of input variables determined, we may substitute these values into the objective function of each quantity-split combination and determine the value for Z. Table 3.4 displays this procedure for Program X.

Step 5: Determine the Recommended Award Allocation

Examine the Z values calculated for each quantity-split combination to determine which one has the lowest numerical value.

The lowest (Z) value identifies the quantity-split combination suggested by this technique. Specifically, it is that combination which was used to generate this lowest (Z) value. For Program X the lowest value for the objective function (Z = 2,694,487) is found in Combination "5" (50% awarded to each contractor), as shown in Table 3.4.

Table 3.4

COMPUTATION OF THE OBJECTIVE FUNCTIONS

Z = [CTB-A + Est. CTD-A] + [CTB-B + Est. CTD-B]

		Contractor A			Contractor B			
C		CTB-A		Est. CTD-A		CTB-B		Est. CTD-B		Z

C		CTB-A		Est. CTD-A		CTB-B		Est. CTD-B		Z
1	Z=[	300,000	+	116,924]	+	[2,520,000	+	279,915]	=	3,216,839
2	Z=[	500,000	+	136,271]	+	[2,200,000	+	198,216]	=	3,034,487
3	Z=[	660,000	+	117,907]	+	[1,890,000	+	128,776]	=	2,796,683
4	Z=[	820,000	+	101,710]	+	[1,710,000	+	191,736]	=	2,823,446
5	**Z=[**	**980,000**	**+**	**87,566]**	**+**	**[1,450,000**	**+**	**177,251]**	**=**	**2,694,487**
6	Z=[	1,170,000	+	105,372]	+	[1,240,000	+	215,494]	=	2,730,865
7	Z=[	1,400,000	+	165,033]	+	[1,050,000	+	276,657]	=	2,891,690
8	Z=[	1,680,000	+	276,461]	+	[760,000	+	240,960]	=	2,957,421
9	Z=[	2,070,000	+	499,575]	+	[500,000	+	238,647]	=	3,308,222

Step 6: Determine Total Annual Award Cost

With the quantity-split decision made, we may calculate the total cost to the Government associated with these award allocations by adding together the bid costs (CTB-A and CTB-B). For Program X, the award quantities determined by the objective function were Q-A and Q-B both being allocated 500 units to produce for the FY1988 buy. The total annual procurement cost for FY1988 in Program X would be:

$$\text{FY88 Total Cost} = \text{CTB-A} + \text{CTB-B}$$

$$= \$\ 980{,}000 + \$\ 1{,}450{,}000 = \$\ 2{,}430{,}000$$

RATIONALIZATION OF THE QUANTITY ALLOCATION TECHNIQUE

If we apply the Minimum Total Cost Rule to the hypothetical data of Program X, we would have allocated 60% to Contractor A and 40% to Contractor B, which would have resulted in the lowest cost to the government for the year. However, one should keep in mind that the market scenario used in constructing the hypothetical data was that Contractor A has the advantage of being the more experienced producer. Therefore, Contractor B is not in a position to compete with A in price. Allocating 60% of the current quantity requirement to A would have exacerbated this problem and put Contractor B further behind in its competitive position.

Our proposed quantity allocation model avoids this problem. The 50-50 split is the result of partially trying to minimize the total cost to the Government and partially trying to minimize the price differential due to price gaming. If we focus on the price differential due to price gaming, then Combination 3 (which would allocate 30% to A and 70% to B) would be adopted. This allocation method would have improved Contractor B's competitive position for future period. Table 3.5 shows the relevant data discussed in this section.

Table 3.5

Total Bid Prices and Estimated Differentials

C	Bid Prices CTB-A	Bid Prices CTB-B	Bid Prices Total	Estimated Differentials CTD-A	Estimated Differentials CTD-B	Estimated Differentials Total
1	300,000	2,520,000	2,820,000	116,924	279,915	396,839
2	500,000	2,200,000	2,700,000	136,271	198,216	334,487
3	**660,000**	**1,890,000**	**2,550,000**	**117,907**	**128,776**	**246,683**
4	820,000	1,710,000	2,530,000	101,710	191,736	293,446
5	980,000	1,450,000	2,430,000	87,566	177,251	264,817
6	1,170,000	1,240,000	2,410,000	105,372	215,494	320,866
7	1,400,000	1,050,000	2,450,000	165,033	276,657	441,690
8	1,680,000	760,000	2,440,000	276,461	240,960	517,421
9	2,070,000	500,000	2,570,000	499,575	238,647	738,222

A CASE STUDY

In this section, we will apply the proposed quantity-split method to a real world case. The identity of the test program is masked and will be referred to as Program Y. The selection of the program was based mainly on data availability. The two contractors will be labeled A and B respectively. Although Contractor B is the second supplier and presumably would be less experienced than Contractor A in producing the product, its step-ladder quotes do show a bid price lower than that of Contractor A at one particular quantity level. Table 3.6 lists the negotiated unit prices for Years 1 and 2 and the step-ladder bids for Year 3. Note that Contractor B's quotes are consistently higher than A's except for the level of 2,934 units. This, of course, is a classical example of price gaming. With our focus on minimizing the Z value (total of award costs and price gaming differential, we will examine how the Year 3 quantity requirements are allocated to the two parties.

Table 3.6

Program Y Price Data
(Constant $)

	Contractor A		Contractor B	
Year	Quantity	Price	Quantity	Price
1	1884	35,936	no production	
2	2029	30,588	1200	38,160
3	424	54,751	424	62,558
	1264	35,078	1264	36,746
	2011	28,976	2011	29,826
	2187	28,504	2187	29,182
	2934	26,554	2934	26,128
	3774	25,569	3774	27,912
	4198	25,774	4198	27,371

With only one negotiated contract awarded to Contractor B, it is impossible to determine the price-reduction curve with objective data. Instead of using an arbitrary number, we used all available data in Table 3.6 to establish a curve. This is, of course, strictly an expedient procedure. No attempt to justify this procedure will be made, as the main purpose is to illustrate the application of the proposed quantity allocation method. The following curves are established using this procedure:

$$\text{Est. CAN-A} = 107{,}152\ (\text{M-A})^{(-.166)}$$

$$\text{EST. CAN-B} = 120{,}226\ (\text{-B})^{(-.193)}$$

Year 3 Allocation Results

When the Year 3 step-ladder bids were utilized by the proposed quantity-split technique, the award allocations thus determined were the same as those using the Minimum Total Cost rule. It can

be seen from Table 3.7 that both the minimum Z value (identifies proposed technique's suggested award combination) and the minimum CTB (identifies MTC rule suggested award combination) occur at the same specific award combination. This selected combination is combination 2: 1,264 units to Contractor A and 2,934 units to Contractor B at a total cost of $120,998,144.

Table 3.7

Program Y Quantity Allocation
(Year 3 Q-T = 4198 units)

C	Quantity Q-A	Q-B	Estimated Cost CTN	Total Bid Cost CTB	Z
1	424	3774	107,640,290	128,554,312	149,468,334
2	**1264**	**2934**	**110,823,312**	**120,998,144**	**131,172,976**
3	2011	2187	111,606,578	122,091,770	132,577,661
4	2187	2011	111,696,604	122,318,334	132,940,064
5	2934	1264	111,180,679	124,356,380	137,532,081
6	3774	424	108,529,435	123,021,998	137,514,562

Note that Contractor B submitted a very competitive bid for 2,934 units, which makes the case less than ideal to demonstrate our proposed quantity allocation technique. If Contractor B is indeed less competitive than A, a more realistic bid for 2,934 units would be approximately $28,500 per unit. Relevant items for quantity combination #2 may be recomputed as follows:

C	Q-A	Q-B	CTN	CTB	Z
2	1264	2934	110,823,312	127,957,590	145,091,868

Allocation #3 would become the recommended quantity-split for Year 3. This would award 2,011 units to Contractor A and 2,187 units to Contractor B, a logical solution to bring B to a more competitive position for future price competition.

CHAPTER 4

QUANTITY SPLIT WHEN COMPETITIVE PRESSURE IS NOT PRESENT

There are two market scenarios in which the contractors would have no incentive to engage in price competition. The first is that one of the contractors does not have the capacity to produce the majority of the annual quantity requirements. This would create a virtual monopoly for the other source at higher quantities. Compounded by the fact that competitive pressure never exists at lower quantities, this market scenario essentially is a duopoly and not a competitive one and should never be treated by the buyer as a competitive market.

The same duopoly market exists if neither contractor is interested in using low prices to capture the larger share of annual quantity, even if the capacity is not a problem. This phenomenon is most likely to be found during a sectoral economic boom.

As discussed earlier in this report, by using the dual source competitive bidding, the Government gives up much of its regulatory authority it enjoys over verification of the contractor's cost and pricing data. Competition allows both parties to exploit the market situation to their own advantage. With the absence of competitive pressure on contractors, the Government loses the only advantage it has in dual source competition. Therefore, continuing the dual source bidding under this market scenario grants a license for profit enhancement to the sellers. In this chapter, we will

discuss the quantity award method under these noncompetitive market scenarios.

PRODUCTION RATE CONSIDERATIONS

The higher bid prices for lower quantities are justifiable according to the theory of economies of scale. This phenomenon is recognized by acquisition analysts in the form of adding another variable to the traditional price-reduction curve (hereafter, learning curve) as follows:[6]

$$Z = aX^bR^c = YR^c$$

where: Y = unit cost of the item as projected on the learning curve, $Y = aX^b$

Z = unit cost of the item, production rate effect considered,

X = cumulative quantity associated with the learning curve computation,

R = production rate measure,

b & c = slopes of the X and R curves.

While this general formulation for production rate is widely used, little has been done to examine the implications of the different ways the production rate factor can be measured. Current practice is to use the annual production quantity as a surrogate

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[6] For example, see John C. Bemis, "A Model for Examining the Cost Implications of Production Rate," Product Engineering Service Office, Defense Logistics Agency, undated; L. C. Cox and J. S. Gansler, "Evaluating the Impact of Quantity, Rate, and Competition," Concepts: The Journal of Defense Systems Acquisition Management, Vol. 4, No. 4 (Autumn 1981), pp. 29-70.

measure of production rate. With this measure, the definition of the **a** of the above equation (referred to as the theoretical first unit cost in learning curve theory) is the unit cost when X=1 and R=1. While this interpretation seems logical, it does result in some awkward numbers, especially in the analysis of annual step-ladder bids, because of the fact that R=1 is not close to the relevant production range.

To illustrate the significance of this issue, let us assume that we have the data of two educational buys which were negotiated by the Government and the contractor, as shown below:

Lot #	Quantity	Unit Price	Algebraic Lot Midpoint
1	100	$43,773	33.9
2	100	31,035	147.0

Since there are only two data points, only the learning rate may be considered. We may use the following formula to determine the learning rate:

$$b = \frac{\text{Log } (Y_2 \,/\, Y_1)}{\text{Log } (M_2 \,/\, M_1)}$$

where M_i represents the algebraic midpoint of each lot. The slope of the learning curve for our illustrative data may now be determined as follows:

$$b = \frac{\text{Log } \frac{31,035}{43,773}}{\text{Log } \frac{147.0}{33.9}} = -0.234422 \text{ or } 85\% \text{ curve}$$

The first unit cost can be readily obtained by substituting the value of b into the basic learning curve equation:

$43,779 = a\ (33.9)^{-0.234422}$

$a = 100,000$

Note that implicit in the above computation is the production rate of 100 units.

Using a Ratio as the Rate Measure

Let us assume that competitive awards will begin in Year 3 and step-ladder bids are solicited from the contractors. The difference in bid prices for various quantity levels during this single year, in principle, should reflect the production rate effect only. Let us further assume that the slope for the rate curve is 80%. If we want to evaluate the reasonableness of bids at different production rate levels, the most logical approach is to anchor the rate measure at a given level within the relevant rate range, e.g., 100 units *(base rate = 100), and measure* different quantity levels as a ratio of the base rate. If the rate curve is known or agreed upon by both parties, the honest bids for various quantity levels may be directly calculated by using the following formula:

$Z = Yr^d$

where

r = the slope of the production rate curve, and

d = the logarithm of R (the rate ratio measure) divided by the logarithm of 2.

For example, with the assumed 80% rate curve, the honest bid for 300 units may be computed as follows:

$$Z_{300} = 25,554(0.8)^{\log(3)/\log(2)} = 25,554(0.8)^{1.585} = 17,942$$

If the parameter value of the rate term is unknown, it can be estimated from annual step ladder bids as follows. Since we define $Z = aX^bR^c$ or YR^c, the ratio of honest bid prices at various quantity levels as a function of the long-term LC may be determined as follows:

$$R^c = Z/Y, \text{ or } Z/aX^b$$

We may use the computed ratios for various bid quantity levels to determine the parameter value for the rate term. Table 4.1 shows the procedures described above.

Table 4.1

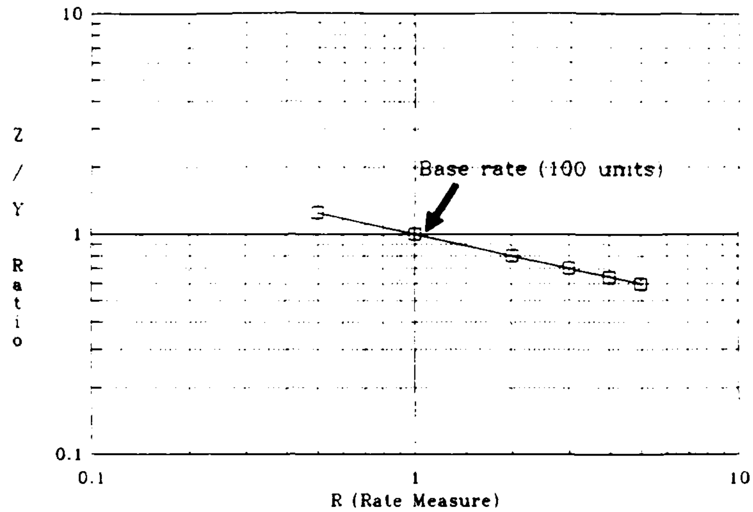
Estimating Rate Effect from Year 3 Step-Ladder Bids

(a = 100000, Total Previous Quantity = 200 units)

Bid Quantity	Midpoint	aX^b (Y)	aX^bR^c (Z)	R^c Z/Y	R Q/100
50	224.9	28,088	35,111	1.250	0.5
100	248.4	27,442	27,442	1.000	1
200	293.5	26,390	21,112	0.800	2
300	336.7	25,554	17,942	0.702	3
400	378.6	24,861	15,911	0.640	4
500	419.5	24,269	14,456	0.576	5

Figure 4.1 shows the relationship between Z/Y and the rate measure, R. Note that the honest bids should reflect a straight line on a log-log graph as shown in Figure 4.1. The slope of the rate curve can be derived from the values of the last two columns of Table 4.1 the same way the learning curve slope is derived. In our case, the exponent, c, is -0.3218, which represents an 80%

Figure 4.1
Production Rate Curve (80%)



curve, the slope we used to generate the hypothetical data.

Using Absolute Lot Size Value as the Rate Measure

If we use the lot size directly as the measure of the production rate, the definition of **a** is necessarily changed to the first unit cost in the LC when X=1 and R=1. Since the rates for the first two buys are not unity, it is impossible to determine the parameter value of the rate term unless there are at least three, and preferably more, data points.

By combining the two education buys and the Year 3 bids, we can derive the parameter values for the Z equation as shown below:

a = 440,352

b = -0.23445 or 85% learning curve

c = -0.321915 or 80% rate curve

The only difference in results is the first unit cost, **a**. The high value of the first unit cost is due to the implicit assumption that it is for X=1 and R=1, which is not close to the relevant production rate range.

The rate effect for Year 3 Step-Ladder bids may be estimated as shown in Table 4.2.

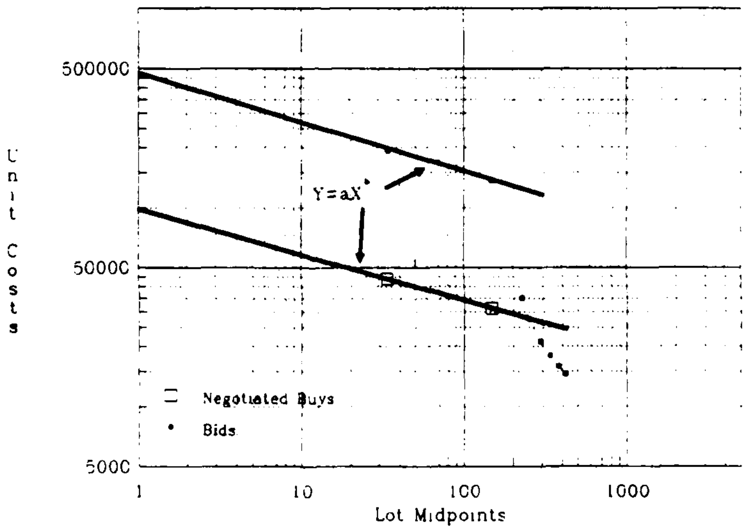
Table 4.2

Estimating Rate Effect from Year 3 Step-Ladder Bids

(a = 440352, Total Previous Quantity = 200 units)

Bid Quantity	Midpoint	aX^b (Y)	aX^bR^c (Z)	R^c Z/Y	R
50	224.9	123,702	35,111	0.284	50
100	248.4	120,853	27,442	0.227	100
200	293.5	116,217	21,112	0.182	200
300	336.7	112,535	17,942	0.159	300
400	378.6	109,483	15,911	0.145	400
500	419.5	106,881	14,456	0.135	500

Figure 4.2
Effect of Alternative Rate Measures



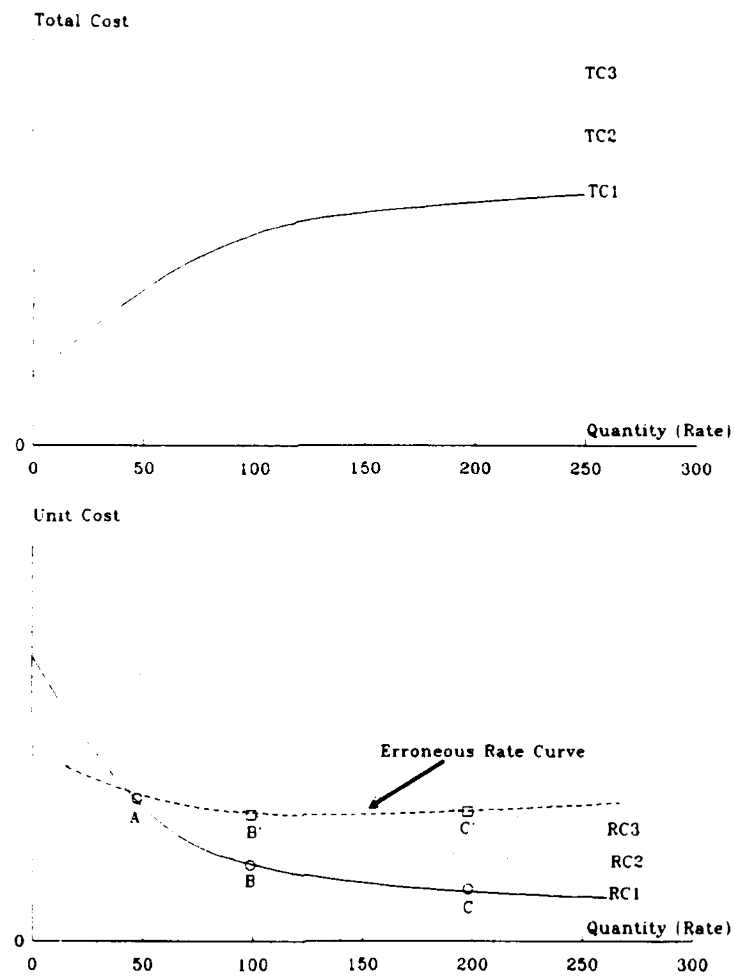
The Y and Z values in Tables 4.1 and 4.2, along with the two educational buys, are plotted in Figure 4.2 for comparison. The top solid line represents the learning curve portion of the Z equation when the rate is measured by the absolute value of the production lot (i.e., a = 440,352) while the bottom solid line represents the learning curve portion of Z when the rate is measured as a function of a base rate (i.e., a = 100,000). Note that the two negotiated buys and step-ladder bids are better represented by the bottom line. What Figure 4.2 shows is that the rate measure should preferably be expressed as a function of a base which falls within the relevant quantity range the contractor is expected to produce.

Other Considerations

There are several other practical considerations that favor the use of a ratio as the rate measure. First, the data base available for LC and rate curve determination is typically scanty. Using unity as the rate base requires both LC and R as the independent variables in parameter determination. Having to use two independent variables reduces the degrees of freedom and increases the estimating error accordingly.

Secondly, while LC captures the effect of cumulative production experience (a continuous phenomenon), the production rate term captures the effect of spreading fixed costs over varying numbers of units. During the early stage of production, the amount of fixed costs may vary from period to period because of the changing

Figure 4.3
Effect of Cost Structure
on Rate Curve



production setup. Therefore, the effect of production rate on unit costs may not stabilize until after the production setup and its inherent cost structure is stabilized. Trying to derive a rate curve with historical data from early stages of production is probably unreliable. Figure 4.3 reflects this problem. Assuming the firm expanded it production setup in the first three years, resulting in higher fixed overhead costs in successive years. The

total costs for each successive years are designated as TC1, TC2 and TC3 respectively. If the Government procured 50 units, 100 units, and 200 units during the first three years, the unit costs to the Government would be Points A, B', and C'. Using these three data point to derive a rate curve would produce an erroneous curve as shown by the dashed line. The slope of the dashed line is flattened by the changing cost structure. On the other hand, the step-ladder bids reflect the spreading of fixed costs in a particular year (Points A, B, and C) and, therefore, are most appropriate for estimating the parameter value for the rate term.

Expressing the production rate as a function of a base rate within the relevant range allows the analyst to estimate the LC from scanty historical data with more confidence and adjust for the applicable rate effect. It also facilitates the comparison of the current step-ladder bids with the historical contract awards.

Let us use our numerical example to illustrate this point. The two negotiated buys were for 100 units each; therefore, the line representing the bids for the third year requirement should cross the assumed 85% LC at a the point which represents the 100 unit base rate level (or $27,442 per unit) and the algebraic midpoint of this lot on the learning curve, if the bids are not inflated. Therefore, we may anchor the contractor's third year step-ladder bids at $27,442 per unit for 100 units along the LC to provide a visual reference point for further evaluation, as shown in Figure 4.1. From this anchor point, we may compute the "honest" bid prices at various quantity levels if the rate parameter is

known or has been agreed upon or estimate the rate parameter if it is unknown. The computational procedure has been discussed earlier in this section.

QUANTITY ALLOCATION TECHNIQUE

When competitive pressure is not present in the market, as discussed in the first section of this chapter, it is necessary for the Government to ensure that the submitted bids are as close to the honest "should cost" as possible. One alternative, used by the Air Force A-10 System Program,[7] is to require a Certificate of Current Cost or Pricing Data after determination of the award split. However, this approach proves ineffective, as it was done <u>after</u> the award split has been determined. The most logical solution is to ensure that the bids are reasonable before they are submitted. This section discusses this approach.

Two requirements must be met if we want to ensure that the contractors do not take advantage of the lack of competitive pressure and submit inflated bids for any level of quantity. First, the step-ladder bids, after adjustment of the learning curve effect, should reflect a straight line on a log-log graph, i.e., Log (Z/Y) vs Log (R) as shown in Figure 4.1. Second, the rate curve representing the step-ladder bids for various production rate level should cross the long-term learning curve at the base

[7] Darrell R. Hoppe, "Dual Award and Competition -- You <u>Can</u> Have Both," paper present at the 1977 Federal Acquisition Research Symposium.

production rate level. Both requirements are necessary in order to discourage the contractor from unnecessarily "loading" the bids at any quantity level. "Loading" the low quantity bids jeopardizes the offeror's profit potential at higher quantity level, and vice versa.

The following four steps briefly describe the proposed quantity allocation method when competitive pressure is not present. A more detailed discussed of these individual steps, along with illustrative examples, will follow.

Step 1: Calculate the Long-term Learning Curves.

> A learning curve should be established for each contractor by using their respective, initial two or more directed buys which should be of equal quantity in order to avoid the effect of different production rate on the learning curve.

Step 2: Request Step-ladder Bids.

> Request step-ladder bids from each contractor for a range of specific quantities of the total annual requirements when each annual procurement solicitation occurs. The bid solicitation should stipulate that the bids, after adjustment for the learning curve effect, should reflect a linear relationship as shown in Figure 4.1 and that the linear line should cross the learning curve at the base rate level.

Step 3: Determine the Total Cost for Each Quantity Combination.
> For each quantity combination, calculate the total cost to the government.

Step 4: Determine the Recommended Award Allocation.

> From the total cost computed in Step 3, determine the quantity combination with the minimum cost.

It should be noted that the proposed quantity allocation method utilizes the same basic rationale as the Minimum Total Cost Rule discussed in chapter 1. The major difference is the bid price

stipulation mentioned in Step 2, which is designed to prevent price gaming.

ILLUSTRATION OF THE ALLOCATION METHOD

The four steps discussed above will be illustrated with a numerical example in this section. We will assume that the historical data for a missile program, Z, from prior directed buys are as shown in Table 4.3.

Table 4.3

Initial Negotiated Annual Awards for Program Z

	Contractor A		Contractor B	
Year	Quantity	Unit Price	Quantity	Unit Price
1	200	$37,404	-	-
2	200	26,390	100	$39,248
3	200	23,331	100	27,077

Step 1: Calculate the Learning Curves.

With three data point, the learning curve for Contractor A may be computed with the familiar power curve function. For Contractor B, it is necessary to use the formula discussed earlier in this chapter to derive the curve from two data points. The procedures have been illustrated earlier. The learning curve equations computed from Table 4.3 data are shown below:

Contractor	Equation	Slope
A	$Y = 100{,}000\ M^{(-.2345)}$	85%
B	$Y = 90{,}000\ M^{(-.2515)}$	84%

Step 2: Request Step-ladder Bids.

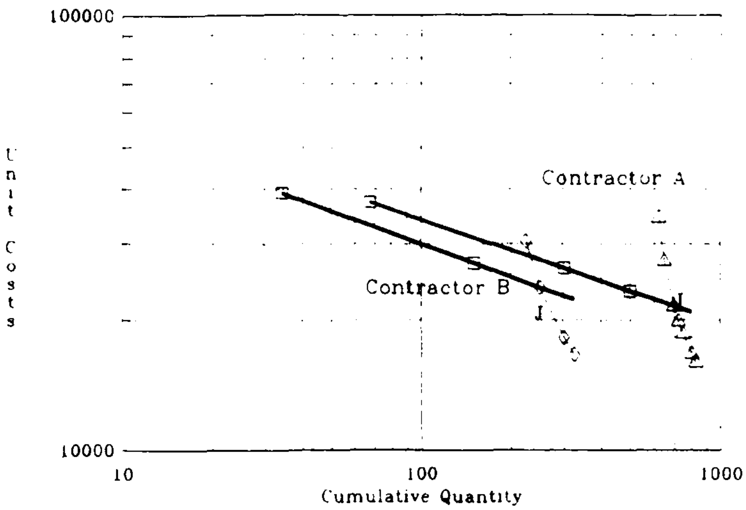
Let us assume that step-ladder bids are to be solicited for quantities ranging from 20% to 80% of the 500 units annual requirement, beginning in Year 4. Let us further assume that Contractor B's production capacity is limited to 250 units per year and, therefore, does not submit bids for quantities above that level. As discussed earlier, the bid solicitation should stipulate that the step-ladder bids, after adjustment for the learning curve effect, should reflect a linear line and that the linear line should cross the learning curve at the quantity level as the directed buys. Table 4.4 shows the possible sets of bid data that satisfy these requirements.

Table 4.4

Year 4 Step-Ladder Bids for Program Z

Bid Quantity	Midpoint	aX^b (Y)	aX^bR^c (Z)	R^c Z/Y	R Q/100
Contractor A:					
50	625	22,101	34,533	1.563	0.25
100	650	21,904	27,380	1.250	0.5
200	700	21,542	21,542	1.000	1
250	725	21,375	19,893	0.931	1.25
300	750	21,217	18,621	0.878	1.5
400	800	20,922	16,738	0.800	2
450	825	20,784	16,009	0.770	2.25
Contractor B:					
50	225	24,327	30,409	1.250	0.50
100	250	23,727	23,727	1.000	1
200	300	22,755	18,204	0.800	2
250	325	22,349	16,640	0.745	2.5

Figure 4.4
Program Z Learning Curves & Annual Bids



The relationship between the step-ladder bids and previous negotiated award prices is shown in Figure 4.4. Note that the line representing A's step-ladder bids crosses its LC at Point I (A's base production rate) while the line representing B's bids crosses its LC at Point J (B's base production rate).

The slope of the rate curve may be determined by regressing the Z/Y ratio on the rate measure (R) using the power curve function, just like the learning curve slope calculation. The rate curve equations computed from the values in the last two columns of Table 4.4 are shown below:

Contractor	Equation	Slope
A	$Z/Y = R^{(-.3218)}$	80%
B	$Z/Y = R^{(-.3218)}$	80%

The slope can be verified by checking the Z/Y ratio when the rate measure is twice its base rate. For example, A's Z/Y ratio for

400 units is 80% of the ratio at 200 units (the base rate), reflecting the 80% curve at the first rate doubling point.

Step 3: Determine the Total Cost for Each Quantity Combination.

Based on the step-ladder bids from each contractor, we may compute the total cost to the government for each quantity combination, as shown in Table 4.5.

Table 4.5

Total Cost of Program Z under Different Quantity Combination

Contractor A			Contractor B			Total
Quan.	Bid	Total	Quan.	Bid	Total	Cost
50	34,533	1,726,641	450	no bid		na
100	27,380	2,738,000	400	no bid		na
200	21,542	4,308,400	300	no bid		na
250	19,893	4,973,339	250	16,640	4,159,968	9,133,308
300	18,621	5,586,200	200	18,204	3,640,800	9,227,000
400	16,738	6,695,040	100	23,727	2,372,700	9,067,740
450	**16,009**	**7,203,842**	**50**	**30,409**	**1,520,438**	**8,724,280**

Step 4: Determine the Recommended Award Allocation.

Based on our calculation shown in Table 4.5, the lowest cost plan for the Government is to award 450 units to A and 50 units to B. Note that the result of this allocation method is contrary to the one discussed in Chapter 3. The method discussed in Chapter 3 is intended for the market scenario in which the incentive to engage in price competition is present but the two contractors have unequal competitive position. Therefore, the proposed allocation method has the partial effect of improving the weaker contractor's

competitive position for future periods.

On the other hand, the allocation method discussed in this chapter is intended for a market in which the incentive to engage in price competition is not present due to economic condition or the lack of production capacity. Therefore, the allocation method focuses on directly addressing the prevention of price gaming and minimization of costs to the Government.

STRENGTH AND WEAKNESS OF THE PROPOSED ALLOCATION METHOD

We stress in the last section that the quantity allocation method focuses on directly addressing the prevention of price gaming. This objective is accomplished through the step-ladder bid stipulation that the bids, after adjustment for the learning curve effect, should reflect a linear line on a logarithmic scale and that the linear line should cross the learning curve at the base production rate level. We will assess the strength and weakness of the allocation method in this section.

In our Program Z example, we assume that Contractor B has production capacity for only 50% of the 500 units to be procured annually, thus leaving Contractor A in virtual monopoly at the higher quantity level. If A is a profit maximizer, a logical price gaming strategy is to "load" the bids for high quantity levels, say $17,422 per unit bid price for 90% of the requirement instead of the honest $16,009. Since the bid solicitation stipulates that the bid curve must cross the learning curve at Point I and the Z/Y ratio must be a straight line, bids for all other quantity level

must be recomputed as shown in Part A of Table 4.6. Note that this seemingly logical bid loading strategy would have resulted in a quantity awarded to A (50/50 split) than without price gaming, thus reducing its profit potential. This disincentive alone would have discouraged Contractor A from loading the bids at high quantity levels.

Table 4.6

Quantity Allocation under Different Price Gaming Strategies

Contractor A			Contractor B			Total
Quan.	Bid	Total	Quan.	Bid	Total	Cost
A's Attempt with Loaded Bids at High Quantity Level						
50	29,882	1,494,118	450	no bid		na
100	25,470	2,546,977	400	no bid		na
200	21,542	4,308,400	300	no bid		na
250	**20,362**	**5,090,487**	**250**	**16,640**	**4,159,968**	**9,250,456**
300	19,425	5,827,594	200	18,204	3,640,800	9,468,394
400	17,993	7,197,168	100	23,727	2,372,700	9,569,868
450	17,422	7,839,886	50	30,409	1,520,438	9,360,324
B's Attempt as a Happy Loser						
50	34,533	1,726,641	450	no bid		na
100	27,380	2,738,000	400	no bid		na
200	21,542	4,308,400	300	no bid		na
250	**19,893**	**4,973,339**	**250**	**15,279**	**3,819,778**	**8,793,117**
300	18,621	5,586,200	200	17,066	3,413,250	8,999,450
400	16,738	6,695,040	100	23,727	2,372,700	9,067,740
450	16,009	7,203,842	50	32,436	1,621,800	8,825,642

Being the second source and with limited production capacity, a common price gaming strategy for Contractor B is to be a "happy loser," i.e., expecting to be awarded the low quantity, B may attempt to load the bid at the minimum sustaining rate level. For

example, Contractor B may be tempted to submit a bid for $32,436 per unit for 50 units instead of the honest $30,409 per unit bid. Again, with the bid stipulation that the step-ladder bids must be anchored at Point J as shown in Figure 4.4, raising the bid at the low end must decrease the bid at the high end. The consequence is the unexpected large quantity awarded (250 units vs 50 units), but at a depressed price. Again, this disincentive should discourage B from attempting to become a "happy loser."

The allocation method addresses the prevention of loaded bids, but not the legitimacy of the slope of the rate curve. One should realize that the slope of the rate curve remains the same only if the production setup remains the same. If the production setup is changed, the slope of the production rate curve as well as the anchoring point will be different. For example, if Contractor B's production facility is expanded, its fixed costs will be increased, which would result in a new rate curve with a steeper slope. The unit cost of producing the minimum 50 units will be higher with the expanded facility than without expansion. This also implies that the anchoring point must be redetermined.

On the other hand, we may argue that changing production setup results in heterogeneous environments which would make any statistical analysis of the rate curve impossible. Therefore, the problem facing the analyst in the determination of the rate curve is not any different from the problem facing the analyst when he/she has to determine a learning curve without any cost history.

CHAPTER 5

SUMMARY AND CONCLUSIONS

Given the multitude of opportunities for bid price manipulation under the dual source competition environment, we discuss the various market scenarios that provide these opportunities. Our premise is that different quantity allocation methods must be developed for different scenarios.

SUMMARY

Factors Contributing to Loaded Bids

In Chapter 2, four major factors contributing to inflated bids were discussed: (1) the minimum sustaining rate, (2) the use of the minimum total cost rule, (3) unequal competitive positions, and (4) the lack of incentive to compete. The minimum sustaining rate factor is a structural issue and cannot be directly addressed. The minimum total cost rule, because of its potential effect on bid manipulation by the contractor, should be treated as an objective and not as a tool in awarding annual quantity requirements. The last two factors both contribute to a noncompetitive environment but they differ significantly from the standpoint of Government controllability. Therefore, effort focuses on developing quantity allocation methods for these two different environments.

Unequal Competitive Positions

When one supplier has an edge in competitive position over the other supplier, the cause of the problem must be redressed by the Government if the future competitive environment is to be improved. If the unequal position is the result of having one contractor further down the experience curve, the problem can be alleviated through the annual quantity allocation made to each contractor. The proposed quantity allocation method under this environment uses an objective function to minimize the sum of award prices and the added costs (or savings) from competitive awards. Under unequal competitive positions, we can expect bid price inflation at low quantities from both suppliers. At higher quantities, only the supplier with the competitive edge would be in a position to inflate the bid price. By minimizing the added costs, the proposed allocation procedure penalizes the supplier who inflates the bids at higher quantities and offers the other supplier an opportunity to catch up, thus improving the future competitive environment.

Competitive Pressure Is Not Present

There are two market scenarios in which the contractors would have no incentive to engage in price competition. The first is that one of the contractors does not have the capacity to produce the majority of the annual quantity requirements. This would create a virtual monopoly for the other source at higher quantities. Since competitive pressure never exists at lower

quantities, this market condition essentially is a duopoly and not a competitive one and should never be treated by the buyer as a competitive market.

The same duopoly market exists if neither contractor is interested in using low prices to capture the larger share of annual quantity, even if the capacity is not a problem. This phenomenon is most likely to be found in a period of economic boom.

By using the dual source competitive bidding under this environment, the Government gives up much of the regulatory authority it enjoys over verification of the contractor's cost and pricing data, thus allowing both contractors to exploit the market situation to their own advantage. Therefore, continuing the dual source bidding under this market scenario is to sanction the seller's profit enhancement strategies.

The difference in step-ladder bids in a particular year essentially reflects the spread of fixed costs over varying number of units produced, or the so-called production rate effect. In Chapter 4, we discussed the measurement of production rate at length. We illustrate the problems of using the traditional LC & rate formula, which estimates the parameter value of the learning curve and the rate curve simultaneously using the same data set. Since the learning curve reflects the cumulative learning experience while the rate curve reflects the production setup, i.e., its cost structure, it is conceptually more logical and operationally more feasible to estimate the parameter of each curve with different data.

The crux of the proposed quantity allocation method under this market scenario is the bid solicitation stipulation that the step-ladder bids, after adjustment for the learning curve effect, should reflect a straight line on a logarithmic scale and that the line should cross the learning curve at the base production rate level, which is initially set at the same level as the directed buys. The allocation of annual quantity requirements is then made by using the minimum total cost rule.

CONCLUDING REMARKS

The two quantity allocation methods discussed in this report vary in their focuses on the grounds that each is intended for different market scenarios. The allocation method proposed for the market scenario with unequal competitive position has a primary objective of enhancing future competitive environments and a secondary objective of minimizing price gaming. An underlying assumption is that true savings to the Government from dual source competition is still possible if the Government can cultivate a true competitive environment. On the other hand, the allocation method proposed for the market in which competitive pressure is not present directly addresses the prevention of bid price manipulation. The underlying assumption is that true savings from dual competition is not possible because the competitive pressure is not present and the only alternative available to the Government is to ensure, within its power, that bids submitted are "honest." Our proposed allocation method is designed to provide a

disincentive to submit loaded bids. This is illustrated with numerical examples.

While the two quantity allocation methods are intended for different market scenarios, it is also possible to have a hybrid method by combining parts of each method. For example, the bid price stipulation may be incorporated into the method proposed for the market with unequal competitive positions. It would have the benefit of preventing bid price manipulation, but the down side of that is the loss of potential true savings. By anchoring the rate curve at a certain point, it takes away the opportunity for truly competitive pricing along with many opportunities for price gaming.

APPENDIX

LIST OF ABBREVIATED VARIABLES

CAB-A = Average unit cost bid by Contractor A

CAB-B = Average unit cost bid by Contractor B

CAN = Average unit cost negotiated

CTB-A = Total bid Cost for that quantity from Contractor A

CTB-B = Total Bid Cost for that quantity from Contractor B

Est. CTD-A = Estimated Total Cost Differential included in the associated Total Bid Cost for an annual procurement quantity for Contractor A. It is the difference between the Total Bid Cost and Estimated Total Negotiated Cost at that quantity.

Est. CTD-B = Estimated Total Cost Differential included in the associated Total Bid Cost for an annual procurement quantity for Contractor B. It is the difference between the Total Bid Cost and Estimated Total Negotiated Cost at that quantity.

Est. CTN-A = Estimated Total Negotiated Cost of an annual award quantity to Contractor A as determined with extrapolation of the corresponding established learning curve involved.

Est. CTN-B = Estimated Total Negotiated Cost of an annual award quantity to Contractor B as determined with extrapolation of the corresponding established learning curve involved.

Q-A = Quantity of Contractor A's annual award

Q-B = Quantity of Contractor B's annual award

Q-T = Total annual award quantity (total annual procurement requirement)

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